4 Battling Nonnative Species and Diseases

A major challenge in protecting natural resources in the national parks is the battle against nonnative species and diseases. Invasions of nonnative plants, fungi, animals, and other organisms threaten the integrity of park ecosystems by

displacing native species, destroying natural habitat, disrupting natural ecological processes, and changing biological diversity in park terrestrial, aquatic, and marine ecosystems. These are very difficult problems with solutions that are often cost-prohibitive and require long-term commitment. Effective management applications include surveillance to anticipate and detect nonnative species invasions and the incidence of disease, application of control treatments, and restoration of damaged resources to a natural condition. Research is also important in revealing the degree of impacts to park resources and in developing intervention techniques. Moreover, both education that raises awareness of the problem and enforcement of regulations are crucial to prevent the unwanted spread of nonnative species. Where processes that degrade resources cannot be controlled, management treatments that reduce other stresses on embattled resources may be helpful. Most of the articles in this chapter expand on these themes; however, two are outside the strict discussion of nonnative species impacts. They are included because they reflect potential impacts of humans on the environment and raise related concerns for the protection of native park species. As the articles indicate, nonnative species and diseases wield a profound influence on the ability of the national parks to preserve park resources and pose very serious implications for the future of these special places.

"Even when alien species can be removed, a community of species that has been changed by evolution remains. Return of native species to an original evolutionary state is impossible, and a 'ghost of alien influence' will remain." — **George W. Cox**

Cattail sleuths use forensic science to better understand spread of an invasive species

By Joy Marburger, Steve Travis, and Steve Windels

ALL CATTAILS ARE NOT CREATED EQUAL. Mounting evidence suggests that a European invader is hybridizing with native cattails in three national parks in the Great Lakes region. This is posing a threat to native biodiversity and causing a "hybrid swarm" into areas where cattails (*Typha* spp.) have never been seen. The invasive narrowleaf cattail (*T. angustifolia*), which has been spreading inland from the eastern seaboard since the early 1800s, has the ability to hybridize with the native broadleaf cattail (*T. latifolia*). In doing so, it has given rise to a new species of cattail (*T.* x *glauca*), first described in the 1960s. This hybrid has the ability to disrupt many ecosystem services traditionally associated with freshwater wetlands. This may be related to its ability to tolerate both of the habitats occupied by its parents (and then some).

All of this comes as no surprise to many taxonomists who have noticed the difficulty in using botanical keys to identify cattail species. However, it did raise questions, including: Why is the variation so extreme? Since most hybrids are sterile, are hybrid cattails fertile? And just how widespread is this phenomenon in our national parks? To find out, biologists with the National Park Service and the US Geological Survey (USGS) began a joint research project. The goal of the two-year study was to uncover the role of hybridization in the spread of cattails in the three Great Lakes national parks. The USGS Park Oriented Biological Support Program and in-kind support from Indiana Dunes National Lakeshore, the Great Lakes Research and Education Center, and Voyageurs National Park (Minnesota) provided funding for the cooperative effort.

This research sends a message that hybridization is an important piece of the puzzle in cattail invasiveness across the Great Lakes national parks.

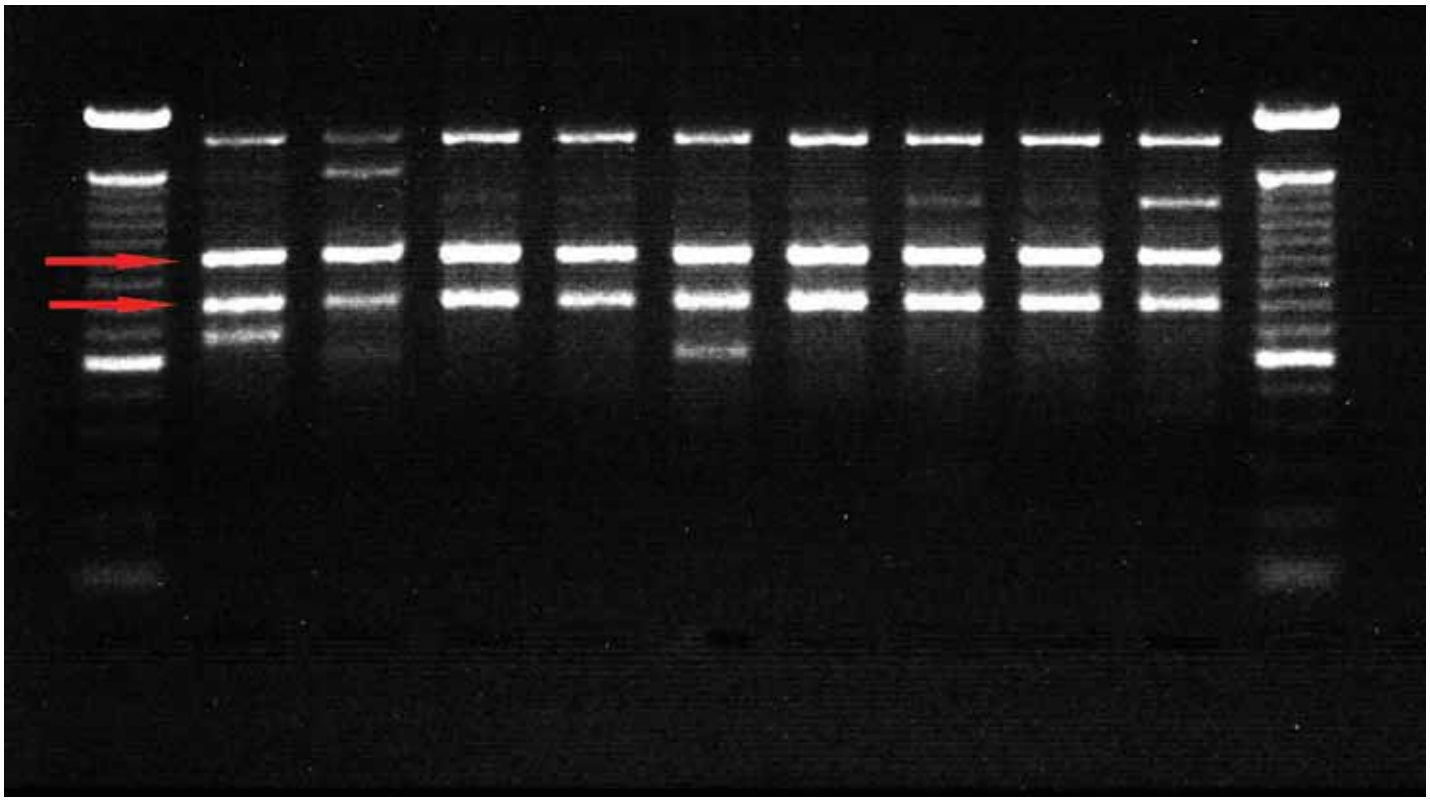
Joy Marburger (Great Lakes Research and Education Center) and Steve Windels (Voyageurs National Park) teamed up with Steve Travis of the USGS National Wetlands Research Center in Louisiana. At this research center, modern molecular techniques are being used to investigate the recent ancestry of invasive cattails and to correlate their hybrid status with their physical characteristics and overall aggressiveness. In 2004 the cattail sleuths collected leaf material from more than 700 plants from wetlands at Indiana Dunes, Voyageurs, and Saint Croix National Scenic Riverway (Minnesota and Wisconsin).

In 2005, results of this genetic analysis provided solid DNA evidence that most of the cattails in the three national park wetlands are, indeed, spontaneous fertile hybrids between *T. angustifolia* and *T. latifolia* or their offspring. The highly variable physical characteristics of the cattail's flowering spikes support this observation. Though a few narrowleaf cattails are still present in the parks, the overall situation

Results of genetic "sleuthing" have provided solid DNA evidence that most of the cattails "swarming" in three Great Lakes national parks are spontaneous fertile hybrids of the native broadleaf cattail (*T. latifolia*, left) and the invasive narrowleaf cattail (*T. angustifolia*, right). Showing up in areas where they have never been seen before, these hybrid cattails are posing a threat to native wetland biodiversity.

A continuous stand of cattail hybrids at Indiana Dunes.

Variability of female cattail inflorescences (spikes) at three national park units (left to right): Indiana Dunes, Voyageurs, and Saint Croix.



DNA analysis of nine cattail leaves from Kabetogama Lake at Voyageurs National Park confirms the hybrid genetic nature of invading cattails. Similar patterns were found in the other two parks. Note that each specimen in the "bar code" has horizontal bands corresponding to genetic material of both *T. latifolia* (the native species, denoted by red arrow at top) and *T. angustifolia* (an invasive European cattail, denoted by red arrow at bottom).

has apparently progressed to the level of what plant biologists commonly refer to as a "hybrid swarm" throughout much of the Great Lakes region. In the easternmost parks, Indiana Dunes and Saint Croix, plants exhibit a greater genetic resemblance to the exotic *T. angustifolia*. At Voyageurs, the most northerly and westerly of the parks studied, the majority of the cattails bear a greater genetic resemblance to the native *T. latifolia* than to their exotic ancestor. In addition the higher incidence of first-generation hybrids at Voyageurs indicates that hybridization is a slightly more recent phenomenon there than at the other two parks.

This research sends a message that hybridization is an important piece of the puzzle in cattail invasiveness across the Great Lakes national parks. Nutrient runoff from urban and agricultural lands, and flood control may also be contributing factors in the spread of hybrid cattails. More ecological testing will be needed to piece it all together. Ultimately, resource managers will gain a clearer understanding of what they must do to preserve the genetic integrity of the pure native cattail and to control the unwanted spread of hybrid cattails in an effort to maintain and enhance wetland biodiversity throughout the Great Lakes region. ■

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Spotted owls face increasing threat in ancient redwoods from invading barred owls

By Kristin Schmidt

RESULTS FROM A 2005 MONITORING PROGRAM in Redwood National and State Parks ("the park") reaffirmed the probability that the ancient redwood forest is losing a key component: the northern spotted owl (*Strix occidentalis caurina*). Listed as a threatened species under the federal Endangered Species Act, the spotted owl earned a place in history as the driving force behind old-growth forest preservation in the West. Now it is facing an increasing threat to its own preservation: the more dominant and aggressive barred owl (*Strix varia*), winging in from the East.

The barred owl, native to the eastern United States, expanded its range into the West in the late 20th century. Subsequently, the number of barred owl sites and the area of barred owl occupancy have increased throughout much of the spotted owl's range. Closely related to the spotted owl, the barred owl now occupies much of the forested habitat in Washington and Oregon. However, it has been slower to invade habitat in California, with one exception: Redwood National and State Parks.

First reported in the northernmost portion of the park in 1982, barred owls were reported in Prairie Creek Redwoods State Park and in lower Redwood Creek in the national park by 1992. In 1993 a three-year inventory of all suitable spotted owl habitat in the park began. Results indicated 35 to 40 territories distributed throughout the park, with core "activity centers" occurring primarily in old-growth forest. Each year since 1993, barred owls have been detected throughout the park with increasing frequency. They now occupy much of the park's suitable spotted owl habitat, including former spotted owl nest trees and core areas around spotted owl activity centers.

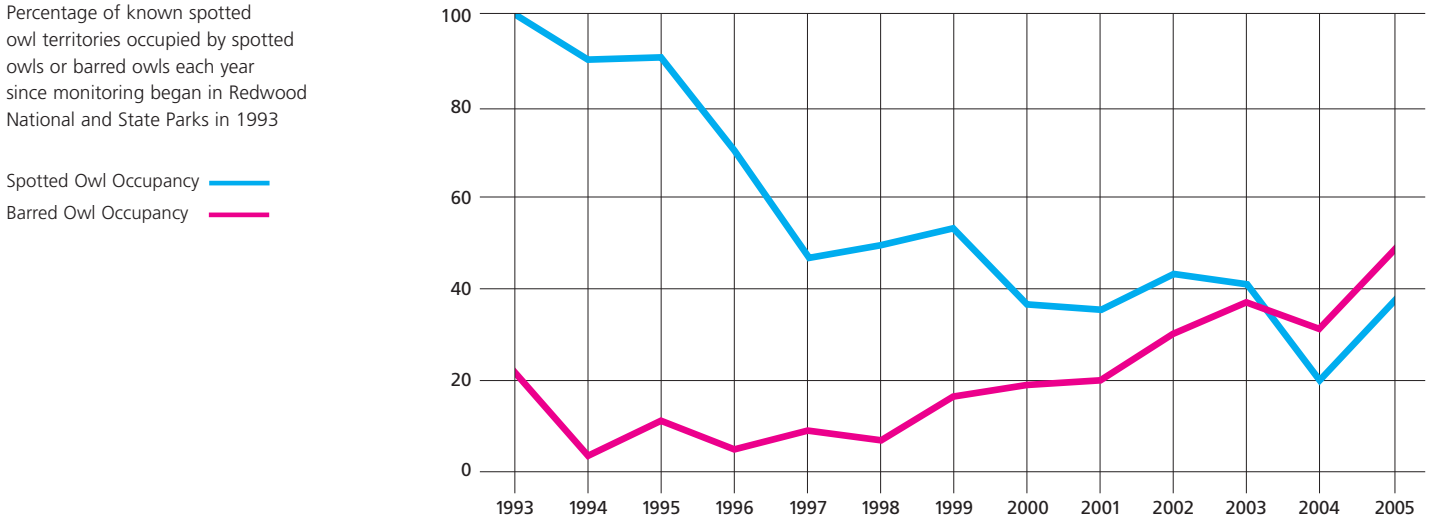
The barred owl, clearly the more dominant of the two owl species, is known to prey on spotted owls, and at least one such event has been documented in the park. Barred owls and spotted owls will hybridize, and anecdotal evidence suggests hybridization between the two species has occurred in the park. Hybridization has not become the significant problem that was predicted at the time the spotted owl was listed as threatened, but the barred owl does appear to affect spotted owl behavior. Each year surveyors find it more difficult to elicit spotted owl responses, the means by which they are located or "moused" to determine occupancy status (e.g., nesting or non-nesting). In 2005, spotted owls were detected at 9 out of 21 territories surveyed within the park, but occupancy status could be determined at only two of these sites. Some sites also contain barred owls, confounding efforts to determine whether spotted owls are present but not vocalizing, or whether they have entirely abandoned their territory.

As of the end of the 2005 field season, an estimated 35 barred owl territories were identified in the park, a number equal to the original quantity of documented spotted owl territories.

In addition to altering spotted owl behavior, barred owls may have a competitive edge. This is their ability to use home ranges that are a fraction of the 3,000 acres (1,215 ha) required, on average, by a spotted owl pair during breeding season. Other competitive

OCCUPANCY OF SPOTTED OWL TERRITORIES 1993–2005, REDWOOD NATIONAL AND STATE PARKS

Percentage of known spotted owl territories occupied by spotted owls or barred owls each year since monitoring began in Redwood National and State Parks in 1993



The spotted owl (above), a key component of ancient forests, is becoming increasingly rare each year in Redwood National and State Parks. The barred owl (right) appears with regularity in the park, occurring both at known spotted owl sites and at locations without a history of spotted owl activity. Biologists are concerned that barred owls are displacing spotted owls through their more aggressive and competitive behavior.

advantages may result from the barred owl's wider prey selection, more consistent reproduction, and larger clutch sizes. Each year, in the course of monitoring known spotted owl sites and inventorying suitable habitat, new barred owl sites are discovered. As of the end of the 2005 field season, an estimated 35 barred owl territories were identified in the park, a number equal to the original quantity of documented spotted owl territories. This estimate may be conservative, since barred owl data were collected incidental to spotted owl surveys. Little is known about barred owl territory size in coastal redwood forests. However, in recent years barred owls successfully produced more fledglings than did spotted owls in the park. In 2005, park staff documented a fledgling ratio of 4:1 for the two species.

Spotted owl inventory and monitoring will continue in the park with the goal of gaining deeper insight into the population status of the two species. Research is sorely needed to gain an understanding of barred owl habitat selection, diet, and home range size. The park is seeking to team up with other parks in the region in similar need of understanding the relationship between the owl species in order to preserve and protect the spotted owl. ■

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Integrating natural and cultural resource management applications in the attack on nonnative plant species

By Elaine F. Leslie

FOR CENTURIES, TRADITIONAL NAVAJO SUBSISTENCE in Canyon de Chelly focused on grazing sheep, farming, and orchards. Today erosion, lack of water, invasion by exotic vegetation, and soil deterioration threaten these potent symbols of the Navajo Nation, with far-reaching consequences for the local economy and canyon families.

In 2005 an unprecedented assortment of partners convened to address a landscape-level invasion affecting the traditional way of life on the Navajo Reservation. The National Park Service, the Navajo Nation, the Natural Resources Conservation Service, the US Geological Survey, and Colorado State University have initiated two projects involving exotic vegetation removal to preserve the historical farming landscape and orchards of the canyon floor.

To implement the daunting task of removing miles of tamarisk (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia*), intermixed with stunning landscapes of native cottonwoods, willows, and sheer canyon walls, the park made a decision to make this more than an exotic plant removal project. In an economically deprived area, job opportunities are few and far between. Therefore, the park set out to employ, train, and implement a local Navajo Conservation Crew, patterned after the highly successful Exotic Plant Management Team model, who could tackle the invasion for years to come. The team's connection to their Canyon de Chelly homeland has overcome the natural barriers created by dense stands of exotic species, as well as some perceived cultural barriers faced by reservation residents.

In 10 months the park's 26-member team has been trained and certified in herbicide and pesticide application techniques, exotic plant removal, and basic firefighting skills. They have treated and contained nearly 100 acres (41 ha) of tamarisk and Russian olive in research plots, canyon-bottom farmsteads, and orchards. Grandmothers and grandfathers, sons and daughters, and now even grandchildren are returning to tend their land and herd their sheep. Public meetings sponsored by the National Park Service now include discussions about native and heritage seeds and crops, farmers' markets, and the return of the traditional churro sheep.

Though initial funding came from the Recreational Fee Demonstration Program, efforts are under way to find additional funding to enable this team to continue the battle with exotic species within the national monument and to assist other park units and reservation lands in similar restoration efforts.

Side by side with local canyon community residents, the Canyon de Chelly team is restoring a vital watershed. In so doing they are restoring the memories, breezes, sunlight, and a traditional way of life to the canyon floor of the national monument. ■

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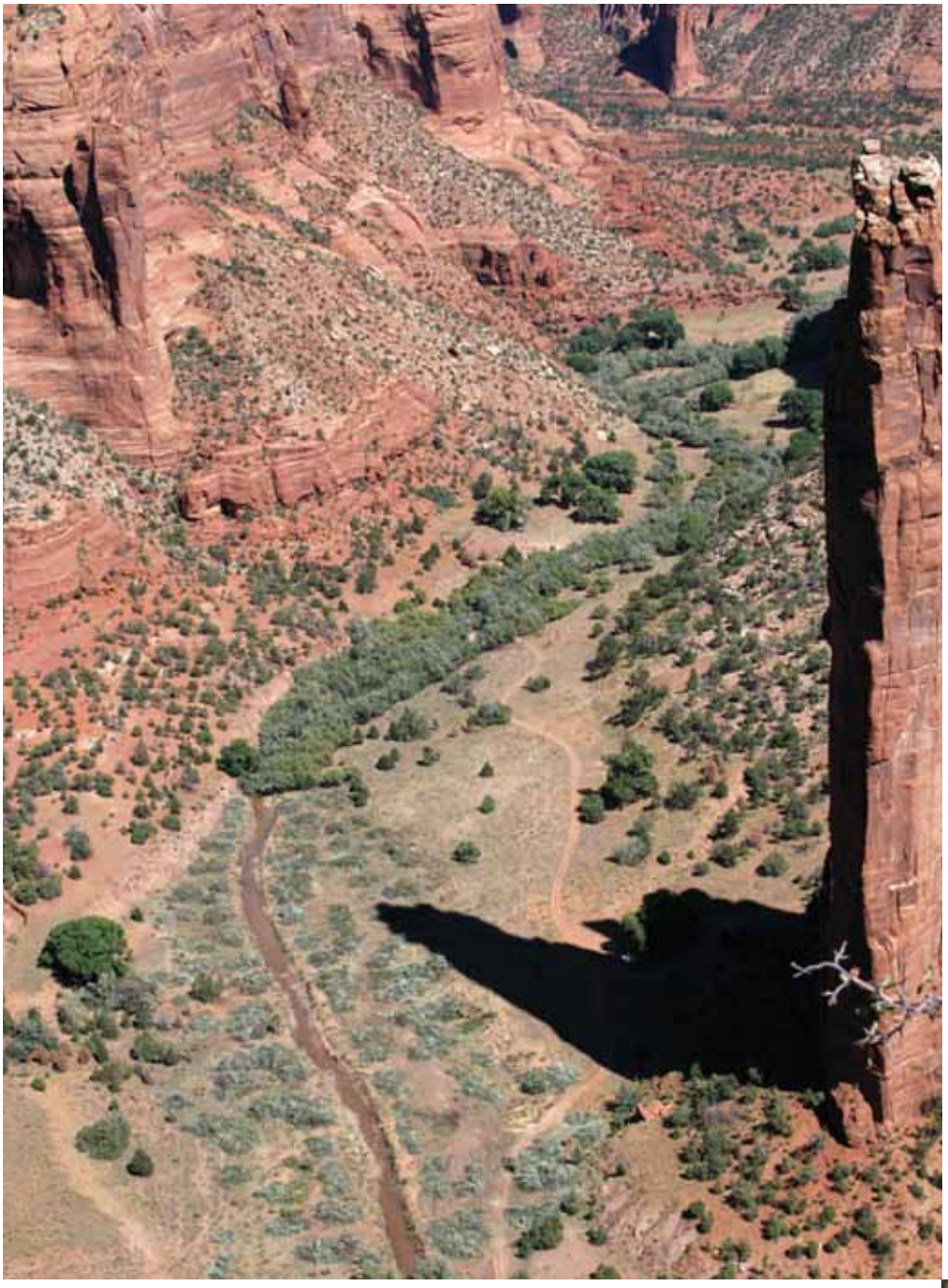

The team's connection to their Canyon de Chelly homeland has overcome the natural barriers created by dense stands of exotic species, as well as some perceived cultural barriers faced by reservation residents.

Nonnative tamarisk and Russian olive are cut and piled on the floor of Canyon de Chelly in the shadow of Spider Rock, an important cultural landmark on the Navajo Reservation and in the Four Corners area. These invasive tree species disrupt traditional lifeways of Navajo residents, alter natural conditions to the point of impairment in some areas, and threaten to replace native cottonwoods and willows. The national monument is at a critical threshold in addressing this issue.

In April 2005 the newly formed Navajo Conservation Crew, made up of 26 Navajo born and raised in the Canyon de Chelly area, began tackling the immense task of cutting nonnative trees and applying herbicide. Wood is distributed to Navajo residents of the canyon for burning and constructing fence posts. Slash is burned or chipped for mulch. Native cottonwoods and willows struggle to reestablish. Ten more years of control efforts like this are needed to bring the invasive species problem at the national monument to a maintenance level.

Disease-resistant American elm to return to the National Mall

By James L. Sherald

IN SPRING 2005 THE AMERICAN ELM (*Ulmus americana*), once nearly wiped out by Dutch elm disease, was given a new chance to thrive in the nation's cities and forests. The National Capital Region's (NCR) Center for Urban Ecology, in cooperation with the USDA Agricultural Research Service's (ARS) Floral and Nursery Plant Research Unit, signed a nonfunded cooperative agreement and began propagating clones of the 'Jefferson' elm, a new Dutch elm disease–resistant American elm cultivar, for imminent release to the nursery industry. The parent tree was discovered among the original elms planted on the National Mall in the 1930s. It was recognized in the 1960s by Horace Wester, an NPS plant pathologist, for its unusual habit of developing leaves earlier in the spring and retaining them later in the fall than its 600 neighboring elms. After several years of subjecting nursery trees to controlled inoculations of the pathogen, first by the Center for Urban Ecology and later by the USDA ARS Floral and Nursery Plant Research Unit, 'Jefferson' has been found to be highly resistant to Dutch elm disease.

The National Mall and Memorial Parks in Washington, DC, manages one of the nation's premier stands of American elm. Though superb in form and tolerant to urban stress, the American elm is notorious for its susceptibility to Dutch elm disease. This devastating disease was first recognized in Washington, DC, in 1947 on the grounds of the Lincoln Memorial. Since then, Washington, like many other municipalities, has lost most of its elms. The National Mall and Memorial Parks, however, through an effective disease management and elm replacement program, continues to sustain a stand of 2,700 elms. Though the annual disease incidence has been low, usually between 1% and 2%, the loss of any elm is significant, particularly of specimen trees, mature and healthy examples of the species. Consequently managers have been very interested in finding resistant elms to reduce future losses and management expense.

Though many elm species, particularly those of European and Asiatic origin, are more resistant to Dutch elm disease than the American elm, they do not have the classic American elm form. Recently, however, several more disease-resistant American elm cultivars have been found. While these trees are not immune to the disease, they are highly resistant and, along with the 'Jefferson,' constitute an exciting prospect for the National Park Service to consider for the possible restoration of this species.

The 'Jefferson' elm is special to arborists in the nation's capital because it was identified among the original plantings on the Mall. The 'Jefferson' has a DNA profile typical of American elm. It can be propagated readily by vegetative cuttings, and over the last few years the National Park Service has grown and planted many 'Jefferson' clones throughout the region. Since 'Jefferson' may eventually become susceptible to a new strain of the pathogen that causes Dutch elm disease or some other disease or insect infestation, the National Park Service will never rely exclusively on 'Jefferson' or any single cultivar in its forest care. Instead, park managers will continue to diversify the population with new resistant selections as they become available. ■

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Resource managers collect softwood cuttings from 'Jefferson,' a Dutch elm disease–resistant tree on the National Mall, for propagation as clones. The USDA Agricultural Research Service's Floral and Nursery Plant Research Unit roots the cuttings in a mist-propagation bed at its field station in Glenn Dale, Maryland, where more than 100 'Jeffersons' will soon be released to interested nurseries.

This young 'Jefferson' elm was planted recently along Jefferson Drive on the National Mall near the parent tree.

Sudden oak death moves east

By Bruce Badzik

FIRST IDENTIFIED IN THE UNITED STATES in the mid-1990s in coastal forests of California, sudden oak death has spread via infected nursery stock to seven nurseries in four East Coast states. The fungus-like organism, *Phytophora ramorum*, that causes the disease has killed more than 100,000 trees and infected numerous other plant species, such as rhododendron (*Rhododendron* spp.), wild rose (*Rosa gymnocarpa*), Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*), and coast redwood (*Sequoia sempervirens*). Investigators have documented the disease in trees at Muir Woods National Monument, Golden Gate National Recreation Area, and Point Reyes National Seashore in California. Though the disease has spread eastward, no forests in eastern national parks have been infected—yet.

No forests in eastern national parks have been infected—yet.

In 2005, researchers at the University of California–Berkeley produced a risk model of disease spread; results showed that the Appalachian Mountains area, home to Great Smoky Mountains National Park, is at high risk if exposed to the organism. Plant pathologists of the USDA Forest Service (USDA-FS) in Asheville, North Carolina, say the threat to forests in the Appalachian Mountains from this disease is "as large as it was from chestnut blight." Hence, a primary issue for NPS resource managers is proliferation of the disease.

In addition to forest plants, *Phytophora ramorum* can spread by the moving and handling of nursery plants. Moreover, hikers and bikers in California have transported the pathogen on the mud of their shoes and bike tires.

According to Susan Frankel, Sudden Oak Death Research Program manager with the USDA Forest Service, investigators sampled for the pathogen in 39 states in 2005, with data reported from twice as many forest locations as in 2004. Thus far, workers from 12 states have submitted 2,038 samples from 519 nursery perimeter locations and 472 forest locations. Researchers have analyzed 62% of the submitted samples and, as of October 2005, all have tested negative for *P. ramorum*. Though the deadly fungus was not detected, sampling continued through November 2005.

In addition, Steve Tjosvold, University of California Cooperative Extension researcher, and Steve Oak and Kurt Gottschalk, USDA Forest Service, initiated a project in 2005 that examines the susceptibility of selected eastern forest and woodland species to the disease. The USDA-FS Pacific Southwest Research Station funded the project. To detect early warning signs of the disease, the National Park Service is seeking additional funding through the NPS Recreational Fee Demonstration Program to conduct further surveys for sudden oak death in national parks throughout the country. ■

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Sudden oak death has spread from the coastal forests of California to the East Coast via infected nursery stock. Thus far, trees in eastern national parks, such as these red oaks in a mixed forest in Great Smoky Mountains National Park, have not been infected. More information about the disease is available at http://www.suddenoakdeath.org.

Tracking the white pine blister rust epidemic in our national parks

By Brent Frakes, Diana F. Tomback, and David Pillmore

LAND MANAGEMENT AGENCIES in North America reached an important milestone in 2005 for addressing the white pine blister rust (*Cronartium ribicola*) epidemic. The National Park Service, working in cooperation with the Whitebark Pine Ecosystem Foundation (WPEF), developed a database for tracking blister rust infection in whitebark pine communities throughout the western United States and Canada. Researchers and managers from the USDA Forest Service (USDA-FS), Parks Canada, National Park Service, Bureau of Land Management, University of Montana, and University of Colorado at Denver and Health Sciences Center comprise the WPEF board. The database serves as a standard repository complete with data analysis tools and reporting options. It has the capability of exporting data to the USDA-FS Forest Health Protection Program, which tracks basic plot information geographically on whitebark pine (*Pinus albicaulis*) and limber pine (*Pinus flexilis*) from numerous surveys and studies, including those from the Forest Inventory and Analysis Program.

The NPS-developed database interfaces with the field protocol that the Whitebark Pine Ecosystem Foundation conceived and field tested. This protocol provides an international standard for measuring blister rust infection. It is efficient in delivering critical information, such as blister rust infection levels and tree damage. Within permanently marked belt transects of whitebark pine communities, investigators tag all assessed trees for future monitoring. By monitoring whitebark pine communities, managers will be able to prioritize areas for restoration, which involves harvesting seeds from potentially blister rust–resistant trees and planting seedlings for reestablishment. Managers of other five-needled white pine communities can modify and use both the protocol and the database for tracking blister rust in those communities.

[The field] protocol provides an international standard for measuring blister rust infection.

White pine blister rust was inadvertently introduced to both eastern and western North America in the early 20th century and has spread throughout the range of western five-needled white pines. It has reached as far south as the Sierra Nevada of California and the Sacramento Mountains of New Mexico, as far east as the Black Hills of South Dakota, and throughout the coastal ranges of British Columbia and the Rocky Mountains of Canada to the northern limit of white pines. Only parts of the Great Basin and "sky island" ranges of southeastern Arizona and southwestern New Mexico remain free of the disease. Though dependent on years with climate favorable to spore production, blister rust continues to spread and seriously threatens western forest biodiversity.

This fungal disease may result in the extirpation of several important subalpine-zone and tree-line species, including whitebark pine and limber pine, from western national parks. Of all pines impacted,

White pine blister rust is an invasive fungal pathogen native to Eurasia that infects only five-needled white pines. It often kills canopies where seed and pollen cones are produced before it kills entire trees, rendering them nonreproductive for years before they die.

In 2005 the Whitebark Pine Ecosystem Foundation developed and tested a field protocol for monitoring white pine blister rust. In most areas of the northern Continental Divide ecosystem, more than 70% of whitebark pine are infected with the fungal disease. In Glacier National Park and on the Blackfeet Reservation, whitebark pine mortality can be as high as 100%. Across the range, blister rust infection levels are now 40% or higher except for the interior Great Basin ranges, the southern Sierra Nevada, and the greater Yellowstone area. According to recent surveys, blister rust now infects about 19% of whitebark pines in the greater Yellowstone area.

however, whitebark is one of the most susceptible to the disease. It is found in all western high-elevation national parks except Rocky Mountain National Park, Colorado, where limber pine occurs instead. Whitebark pine is a keystone species throughout its range, reducing soil erosion and protracting snowmelt at high elevation, pioneering after fires and paving the way for regeneration of other species, providing habitat at high elevation, and supplying wildlife food in the form of large nutritious seeds. In the greater Yellowstone area, whitebark pine seeds are an important food for grizzly bear (*Ursus arctos*) and black bear (*Ursus americana*) prior to hibernation.

Though the database and protocol are only a first step in addressing the blister rust problem, they are important milestones for land management agencies in North America. They standardize and integrate data, fostering cooperation and information sharing and enabling a holistic response to natural resource threats on federal lands and across an international border. ■

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Combating the hemlock woolly adelgid in Great Smoky Mountains National Park

By Tom Remaley and Carey Jones

AT GREAT SMOKY MOUNTAINS National Park (Tennessee and North Carolina) the results of insecticidal treatments of hemlock woolly adelgid (*Adelges tsugae*) have been dramatic. Hemlock woolly adelgid is a small aphid-like insect native to Asia that feeds at the base of hemlock needles and can cause tree mortality in as few as three years. Trees with ashen-gray foliage before treatment recover their color and produce new growth. Treatments include spraying insecticidal soap on trees in developed areas and along roadways, applying systemic insecticides directly to the soil, and injecting insecticide into the trunks of especially large trees or those inaccessible by vehicle. Additionally, park biologists released a predatory beetle (*Sasajiscymnus tsugae*) as a biological control in 78 areas with old-growth eastern hemlock (*Tsuga canadensis*) stands throughout the park. This and other biocontrols currently under development provide the best hope for control of the adelgid and survival of the hemlock forests. Supported by funds from the Friends of Great Smoky Mountains National Park, USDA Forest Service, and National Park Service, park managers (with a 12-member crew) treated more than 2,000 acres (810 ha) in 2005; they have aggressively managed the insect since its discovery in 2002.

"Without the Friends of the Smokies and [other] supporters … we might not have the option of bio-control, which provides the greatest hope … for a permanent resolution [to] the invasion of the hemlock woolly adelgid."

—Dr. Carl Jones, Department of Entomology and Plant Pathology, University of Tennessee

Investigators have now identified hemlock woolly adelgid throughout Great Smoky Mountains National Park. The insect has the potential to eliminate hemlock trees from the landscape; by comparison, almost 95% of the hemlocks in Shenandoah National Park have been lost to the infestation. Great Smoky Mountains National Park contains more than 800 acres (324 ha) of old-growth eastern hemlock, the most of any unit in the National Park System. Hemlock forests are widely distributed over almost 90,000 additional acres (36,450 ha) in the park. Some of the largest eastern hemlocks known, commonly exceeding 150 feet (46 m) tall and as much as 6 feet (2 m) in diameter, inhabit the park.

Although the adelgid will fundamentally and forever alter the hemlock forests of the Smokies, with continued funding, dedicated staff, and committed partners, future visitors to the park will still be able to marvel at the "redwood of the East." Public education has led to significant fundraising for control of hemlock woolly adelgid, including efforts that involve the Great Smoky Mountains Association, Friends of Great Smoky Mountains National Park, and local schools, civic groups, and businesses. These fundraising efforts prompted the establishment of an additional beneficial insect lab at the University of Tennessee, funding of field crews, and provision of supplies and equipment. A prime example

In addition to spraying insecticidal soap on trees to combat hemlock woolly adelgid, public education is a strong part of control efforts at Great Smoky Mountains National Park. Outreach includes TV, radio, and newspaper progress reports; the Save Our Hemlock Web site at http://saveourhemlocks.org; presentations to local civic clubs; community and teacher workshops about controlling the adelgid; ranger-led public hikes that study the insect in the field; educational handouts and posters distributed in the park and neighboring communities; and, of course, word of mouth from the many citizens who support the efforts to control infestations in the park's hemlock forests.

of partner support is the Great Smoky Mountains Association's creation of a "Save the Hemlocks" T-shirt. In 2005 the public sale of this item generated $70,000, all devoted to raising beetles at the University of Tennessee lab. (The sale of each shirt pays for about a dozen predator beetles.) The integration of public education in this program illustrates how outreach and awareness can result in financial and procedural support for addressing a serious natural resource threat. ■

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Avian influenza: What is the threat to our national parks?

By Margaret A. Wild, David Bleicher, and Charles Higgins

THE NATIONAL PARK Service's Public Health, Risk Management, and Wildlife Health Programs are working closely with other NPS programs and federal agencies in planning for surveillance and response to the Asian strain (H5N1) of highly pathogenic avian influenza (HPAI). A top news story for 2005, avian influenza, known as "bird flu," was responsible for 94 laboratory-confirmed cases of human disease, with 41 human fatalities. At present, however, the disease primarily affects domestic and wild birds and has not acquired the ability for sustained human-to-human transmission, though this possibility is a real concern. In order to control spread of the disease, authorities in affected countries culled millions of domestic poultry, ducks, and geese. Yet what impact might this disease have on the staff, visitors, and wildlife in our national parks?

Although the media has given ample coverage to the threat of disease spread by migratory birds, human-assisted movement of domestic or wild birds, particularly illegal movement, is likely to be a more serious threat.

Avian influenza viruses occur naturally in birds, particularly those living in and around water. Some avian influenza viruses cause no ill effect in birds; a percentage of wild birds worldwide carries these low-pathogenic avian influenza viruses. However, the Asian strain of H5N1 has mutated in infected domestic birds to become pathogenic to birds, humans, and some other mammals. Because of these changes, the National Park Service would consider the virus to be an exotic organism if introduced into US national parks.

Though the highly pathogenic H5N1 strain has not been identified in North America, the threat of introduction looms with its spread in Asia and eastern Europe. The three most likely routes for its introduction into the United States are migratory birds, human-assisted movement of wild or domestic birds, and human-human transmission. If migratory birds were to introduce HPAI into this country, the virus would probably arrive first in Alaska with birds from Asia in the spring. Infected birds from Asia could then mix with birds from other flyways that share summer grounds in Alaska. In fall these birds could carry the infection down flyways to the lower 48 states. Although the media has given ample coverage to the threat of disease spread by migratory birds, human-assisted movement of domestic or wild birds, particularly illegal movement, is likely to be a more serious threat. This type of introduction could occur at any place or time. Finally, if sustained human-to-human transmission develops, persons entering the United States could introduce HPAI into this country.

Though avian influenza has not been identified in North America, bird migration from Asia to Alaska, and in turn from Alaska to the lower 48 states, is a plausible way for the virus to be introduced into the United States. In 2005 the National Park Service emphasized planning for surveillance and response to the pathogenic strain of the disease in order to protect human and wildlife health in national parks.

Although public health officials do not know if an avian influenza pandemic will occur, biologists predict that if HPAI reaches this country, mortality in both domestic and wild birds will almost certainly occur. The level of mortality and the species of wild birds that would be affected are not known. However, based on other avian influenza subtypes, biologists expect HPAI to affect primarily waterfowl such as ducks, geese, and swans, and to a lesser extent, shorebirds such as gulls. Although no data suggest that culling wild birds would control an outbreak, significant public or political pressure may build to "do something," but this type of control effort in wild bird populations is not logistically or environmentally feasible.

So what can be done? In wildlife management, surveillance for H5N1 in wild birds is important and is best accomplished by being alert to and investigating unusual mortality events. Field biologists can decrease the risk of HPAI by reducing inhalation of aerosols such as dust, feathers, or dander; wearing personal protective equipment; and washing hands and disinfecting equipment after use. Park staff should encourage visitors to enjoy wildlife from a distance, and in

particular, not to touch dead animals but instead report them to natural resource managers.

Should HPAI gain the ability for sustained human-to-human transmission, the National Park Service could implement a number of tools for managing an avian influenza pandemic. Simple hygienic preventive measures like coughing into one's sleeve and washing one's hands would become critical in a disease outbreak. Park operations could be significantly impacted in response to a pandemic, including the potential for park closures, implementation of public access and interaction policies, restrictions on movements and the use of law enforcement to enforce these restrictions, and the need for protection of emergency medical system providers. Other methods of disease control could include isolation of sick individuals, quarantine to limit the movement of all individuals, education of the public and park employees, use of antiviral agents, and vaccination if an effective vaccine is available.

Regardless of whether a pandemic occurs, information and knowledge will facilitate prudent planning and preparation, allowing the National Park Service to be prepared to protect park natural resources and employee and visitor health. More information about avian influenza and NPS response planning is available at http://www.nps.gov/public_health/zed/ai/ai.htm. ■

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Earthworms return to forests of the western Great Lakes region

By Suzanne Sanders

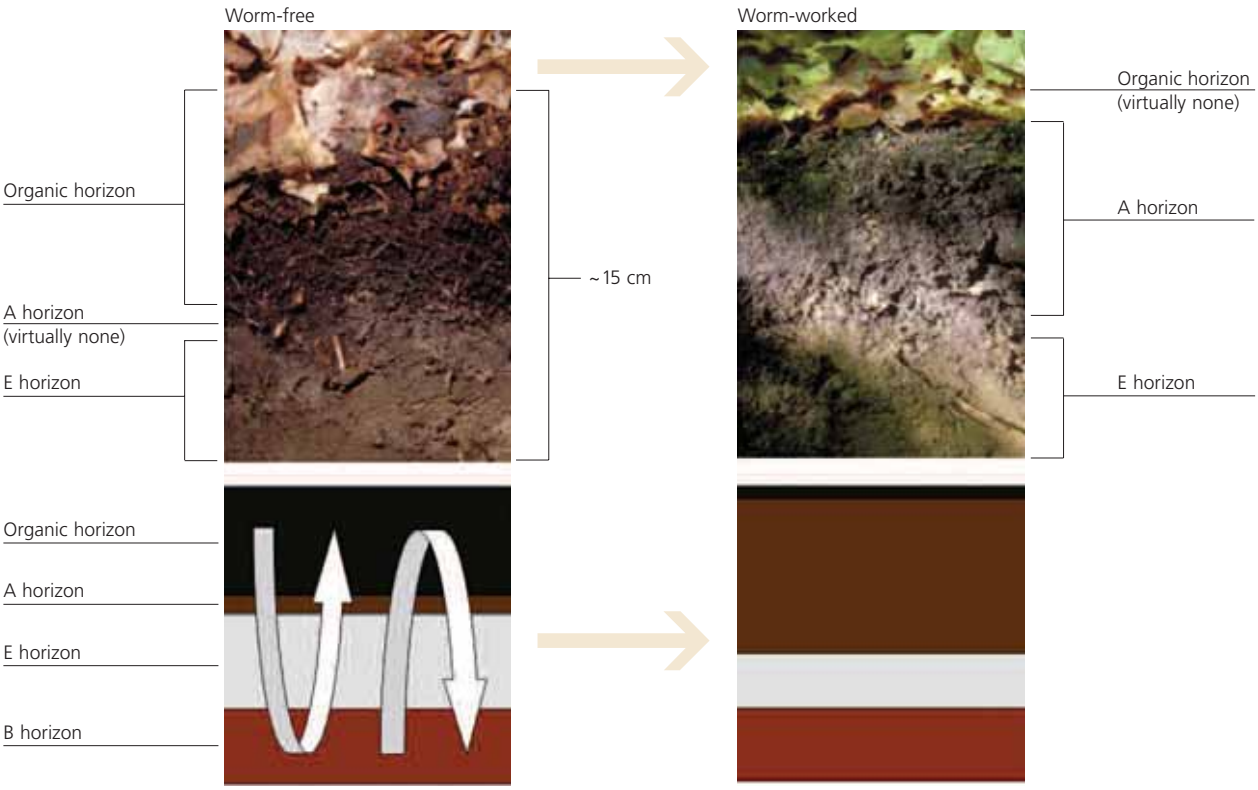
MOST PEOPLE ARE SURPRISED TO LEARN that earthworms are not native to many areas of the northern United States, including parts of Minnesota and Michigan. Scientists assume that earthworms were once native to this region but disappeared during the last ice age when glaciers covered a large part of the continent. Now the earthworms are working their way back, introduced in part by anglers. Research has documented the impact of exotic earthworms on sugar maple forests, but little is known about their effects on other forest types. The Great Lakes Inventory and Monitoring Network funded a two-year study (2004–2005) to inventory exotic earthworms in beech-maple forests at Pictured Rocks National Lakeshore (Michigan) and in aspen-fir forests at Voyageurs National Park (Minnesota), and to test for relationships among earthworms, soil characteristics, and plant communities. The study was carried out by Cindy Hale and George Host of the Natural Resources Research Institute of the University of Minnesota.

Scientists assume that earthworms were once native to this region but disappeared during the last ice age when glaciers covered a large part of the continent. Now the earthworms are working their way back, introduced in part by anglers.

Earlier research had shown that earthworms change the soil in the top three layers of the soil profile. Forest soils that formed in the absence of earthworms have a thick, organic surface layer. Below it is the "A horizon," a mineral-mixed-with-humus layer that in this environment is characteristically thin, and underlying it is a leached, sandy loam layer, the "E horizon." This profile supports diverse plant communities adapted to these soil conditions. However, earthworms mix the soil horizons so that the organic layer above and the E horizon below are incorporated into and expand the A horizon. In sugar maple forests this soil disturbance impacts the understory plant community and may facilitate the establishment of invasive plants, an area of future research.

Investigators in the Great Lakes Network study found that only 3 of 40 sites sampled were free of earthworms, despite the fact that 20 sites were predicted to be at low risk for invasion. Five earthworm species were found in both forest types, though the total earthworm biomass in the aspen-fir forests was only about half that in the beech-maple forests. This earthworm biomass, in turn, was approximately half that reported for sugar maple forests by other researchers. In addition, this study found that where earthworm species richness and biomass were greatest, the organic horizon was thin and the underlying A horizon was thicker, supporting the results of other investigations. In contrast to the results of research in sugar

SOIL PROFILES, VOYAGEURS NATIONAL PARK, MINNESOTA



The introduction of earthworms in two kinds of northern forests threatens native understory plants by changing the soil profile. The soil before earthworms arrive has a thick organic layer at the surface, underlain by a thin mineral-mixed-with-humus (A horizon) layer, underlain by a leached, sandy loam layer.

Earthworms mix these layers, creating a thick A horizon at the expense of the other two layers. The resulting soil is less hospitable to the native understory, possibly rendering it vulnerable to exotic invasive plants, a situation of concern to managers.

maple forests, however, this study did not find adverse impacts on forest understory plant communities.

The presence of earthworms at the two parks is widespread, although the herb-layer diversity suggests that invasion occurred relatively recently. One key aspect of earthworm spread is that it is slow, averaging only 16 to 32 feet (5 to 10 m) per year. The most effective management policy is one that emphasizes minimizing the establishment of new inoculation points for earthworms through a combination of public education and increased enforcement of regulations. ■

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Coral bleaching and coral disease: A damaging combination for reefs in Virgin Islands National Park

By Jeff Miller and Matt Patterson

WHILE A RECORD NUMBER OF TROPICAL STORMS and hurricanes battered coral reefs in Florida and the Caribbean in 2005, below the surface two forces combined into a "perfect catastrophe" scenario for coral reefs. Outbreaks of the coral disease "white plague" occurred as a Caribbean-wide coral bleaching event produced extreme levels of coral mortality. Monitoring in 2005 revealed extensive coral bleaching and disease-caused coral mortality at sample sites in Virgin Islands National Park and Buck Island Reef National Monument. Scientists with the South Florida/Caribbean Network (SFCN) monitor coral reefs in four parks in the Southeast Region: Dry Tortugas, Biscayne, and Virgin Islands National Parks, and Buck Island Reef National Monument. South Florida parks escaped the bleaching occurring in the Virgin Islands parks in part because of cooler water temperatures that accompany the passing of tropical storms and hurricanes.

Corals bleach in response to stress, and in 2005, record high water temperatures caused this to occur in coral reefs around the US Virgin Islands.

An ongoing, eight-year monitoring program at Tektite reef in Virgin Islands National Park looks specifically at white plague. Average live coral-cover on the study transects at Tektite reef has declined by 46.7% (from an annual average of 66.5% in 1997 to 44.5% in 2005). Compounding the problem, this disease principally affects the most abundant and major reef-building coral species, star coral (*Montastraea annularis*), which grows extremely slowly at 0.04 to 0.08 inch (1 to 2 mm) per year and has very low recruitment (coral larval settlement and growth) rates. In addition to long-term monitoring, network scientists work with universities and groups such as the Coral Disease and Health Consortium to determine the drivers of coral diseases. US Geological Survey (USGS) scientists focus on disease etiology, including experimental, nondestructive sampling techniques in which investigators take swabs of healthy and diseased coral tissue, which are later analyzed for microbial communities and coral genotypes.

Coral bleaching began in late summer and continued into December 2005. This bleaching occurs when the symbiotic algae within the coral tissue are expelled. These algae, called zooxanthellea, provide the coral with energy and its greenish brown color. When the algae are expelled, the coral loses its color, appearing white or bleached. Corals bleach in response to stress, and in 2005, record high water temperatures caused this to occur in coral reefs around the US Virgin Islands. Long-term effects of the bleaching depend upon duration and severity (i.e., complete or partial loss of the zooxanthellea). The last bleaching event to affect this area occurred in 1998 and caused low levels of coral mortality. However, researchers are concerned that record warm water temperatures in August and September 2005 may make this bleaching episode more severe than the one in 1998.

Bleaching of *Montastraea annularis* and *Porites porites* (head corals, facing page, left column) started in August 2005, but corals showed partial recovery by October 2005. By contrast, bleaching caused complete mortality of an *Acropora palmata* (elkhorn coral) colony (right column) by 26 October 2005.

As of November 2005, color was returning to the "head" corals (*Montastraea*, *Colpophyllia*, *Diploria*, and *Siderastrea* species), indicating that mortality from bleaching may be low. The November white plague disease outbreak, however, has caused tremendous mortality to these same species that seemingly survived the bleaching. Whether the bleaching has made them more vulnerable to the disease is not yet known. Also, elkhorn coral, a species that is rarely affected, bleached during this severe event and has incurred substantial mortality. The elkhorn and staghorn corals (Caribbean *Acropora* genus) have been recommended for protection under the Endangered Species Act, a highly unusual occurrence for marine invertebrates.

In a year of record levels of storm activity, coral reefs were under attack from more than just hurricanes; coral disease and coral bleaching from elevated water temperatures combined with hurricanes to cause extensive coral mortality. Continued monitoring will document the total amount of mortality. As scientists with the South Florida/Caribbean Network continue to gain understanding of coral bleaching and disease, future endeavors may provide ways to mitigate these stresses and promote a more resilient coral reef ecosystem. For example, the Coral Reef Task Force—established in 1998 by presidential executive order to lead US efforts in preserving and protecting coral reef ecosystems—passed a resolution to take action in response to the 2005 Caribbean bleaching episode. These efforts are significant because not only do coral reefs attract millions of visitors to the National Park System each year, they serve as structural barriers that protect our shorelines from storm-generated waves. ■

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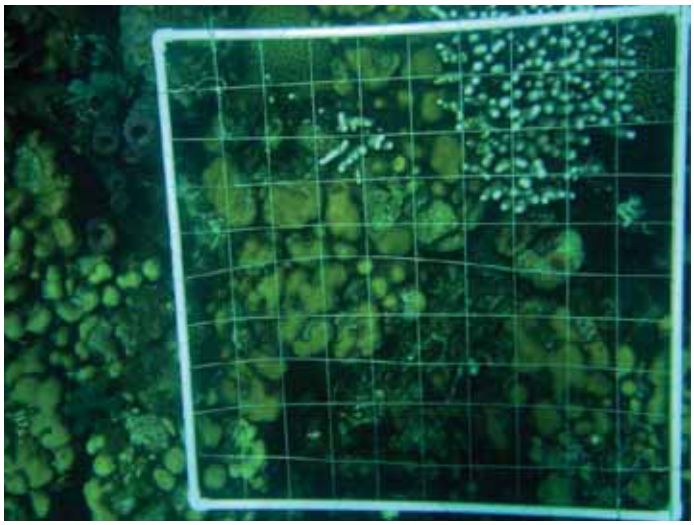

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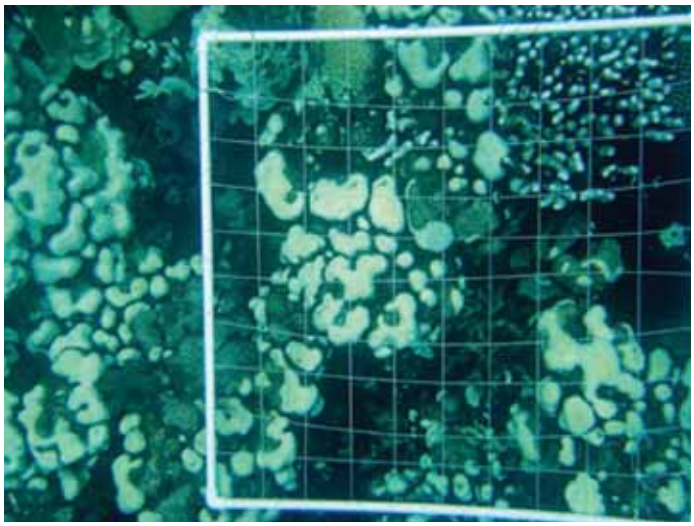

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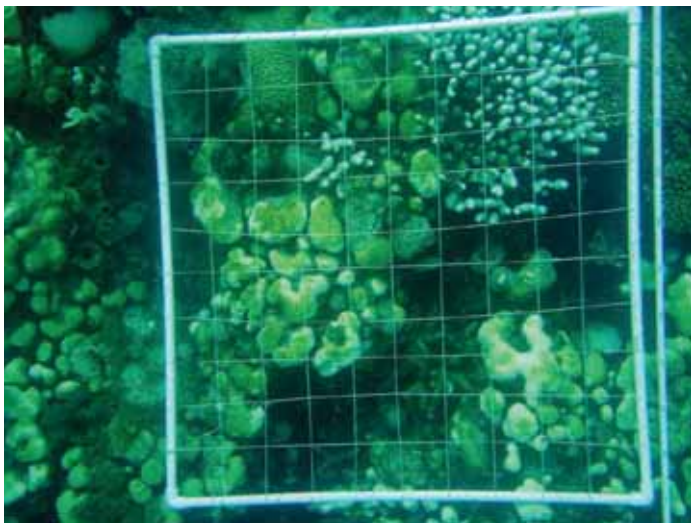

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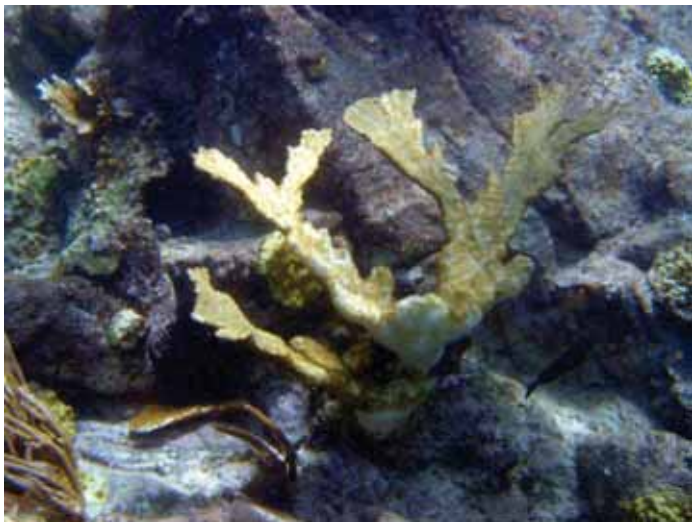

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